RELATIONSHIP BETWEEN SEEDLING LENGTH AND PLANT HEIGHT AND ITS IMPACT ON THE SELECTION OF SHORT PLANT IN RICE*

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Heavy fertilization has been an effective way for increasing rice grain yields. However, increased application of fertilizers generally accompanies with the increase of plant height (Chang, 1968). Inasmuch as plant height is a major factor in determining varietal resistance to lodging (IRRI, 1966), tall plants appear more susceptible to lodging. It has been clearly demonstrated that lodging causes an appreciable losses in yields of rice (Jennings and Sornchai, 1964). Thus, significant increase of rice yields through heavy fertilizer application appears unlikely before considerable improvement in lodging resistance has been made. It is quite natural, therefore, that the development of short stature varieties with favorable lodging resistance and nitrogen responsiveness has constituted the major objective in our rice breeding program.

Selection for plant height is traditionally done in the paddy field when rice plant are fully matured. Since plant height is mostly controlled by a single pair of alleles and a few modifiers, with tall stature being either completely or incompletely dominant over short one (Aquino and Jennings, 1966 ; Chang et al., 1965 ; IRRI, 1965, 1966), rice plants in the F_2 population of the crosses involving the tall and the short varieties are expected to segregate into either 3 tall: 1 short or 1 tall: 2 intermediate: 1 short ratio. Thus, when selection for plant height is made in F_2 population, a majority of the taller plants will be eventually discarded, resulting in the waste of time, land, and capital inputs. However, if the potentially tall plants can be properly eliminated at the seedling stage, more space in the paddy field can be made available for the transplanting of short plants. As a result, chances of obtaining short plants combined with other desirable traits can be greatly increased.

The objectives of this investigation were (1) to measure the relationship between seedling length before transplanting and plant height among rice varieties of different plant types, (2) to determine the possibility for selecting short plants based on the length of seedlings in the nursery, and (3) to estimate the heritability values of seedling length in some F_2 populatoins of rice.

MATERIALS AND METHODS

A total of 95 and 94 rice varieties were randomely selected in the first and the second crops of 1969 respectively for the calculation of correlation coefficients between seedling

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length and plant height at various growing stages. In the first crop, there were 19 varieties of indica type and 76 varietes of japonica one whereas in the second crop, the varieties consisted of 17 indica type and 77 japonica one. Both tall and short stature varieties were included in each type of rice. The length of seedling was measured on the day of transplanting by using seedlings of representative growth of each variety. Plant height was measured once every 30 days from transplanting up to the full maturity of rice. Twenty measurements were made for each variety in both seedling length and plant height and the average values of both characters were used for the calculation of the simple correlation coefficients. Coefficients of determination (r^2) were also calculated to show the percentage of plant height variation determined by seedling length before transplanting.

The possibilities of selecting short plants based on the seedling length in the nursery were investigated in the first and second crops of 1969. The experimental materials consisted of three F_2 populations each from an intra-japonica, an indica- japonica, and an intra-indica crosses. For intra-japonica crosses, C 223 x Pi No. 4 was used in the first crop and Line 54233 x Nohrin 22, in the second one, whereas indica-japonica cross, Chianung 242 x IR 9-30, and intra-indica, cross Taichung native 1 x Century Patna 232 (CP 231) were used in both crops. C 223, Line 54233, Chianung 242, and CP 231 were used as tall parents whereas Pi No. 4, Nohrin 22, IR 9-30, and Taichungnative 1, as short ones. F_2 as tall and parental seedlings were grown in the ordinary wet nursery. On the day of transplanting, F_2 seedlings were visually classified into tall, intermediate, and short groups with unselected seedlings used as the control .These four groups of F_2 seedlings together with both parents were arranged in a randomized block design experiment with 3 replications. Individual plots consisted of four rows with 4 m in length. The plant spacing was 25 x 20 cm with one seedling per hill. Standard cultural practices were followed for the management of the experimental plots.

After transplanting, 60 plants were selected at random to represent each group of F_2 and parents and data for plant height, heading date, number of panicles, and grain yield were obtained from each plant. Plant height was measured once every 30 days up to the full maturity of rice plant. Genetic variances were also calculated to compare the efficiency of visual selection of plant height based on the seedling length brfore transplanting. Heritability in broad sense was determined for seedling length and plant height at various growing stages based on data obtained from unselected F_2 populations. F_2 variance method used by Mahmud and Kramer (1951) was followed in the calculation of heritability values.

EXPERIMENTAL RESULTS

Relationship Between Seedling Length and Plant Height in Rice Varieties.

Correlation coefficients between seedling length and plant height at vario us growing stages are presented in Table 1. Seedling length measured just before transplanting was

found to be highly correlated with plant height during the early stages of growth in both crops. However, the magnitude of correlations gradually decreased with the progress of rice development. When rice plants were fully matured (about 120 and 90 days after transplanting in the first and the second crops, respectively), the correlation coefficient between seedling length and plant height in the first crop failed to reach a singificant level whereas in the second one it remained to be significant at the 1% level, although the magnitude of correlation was rather small. Coefficients of determination (r^2) revealed that more than 30% of plant height variation in both crops could be ascribed to the effect of seedling length before transplanting. However, its influence declined rapidly and at heading stage (about 90 and 60 days in the first and second crops, respectively), seedling length was able to determine only 12% of the variation in plant height. The coefficients of determination reduced to about 3 and 11% in the first and the second crops respectively when rice plants reached the final stage of growth.

Table 1. Correlation coefficents and coefficients of determination between seedling length before transplanting and plant height at various growing stages in randomly selected varieties of rice.

Crop season	Coefficent	Days after transplanting				Degree of freedom
		30	60	90	120	
First crop, 1969	Correlation (r)	0.5477**	0.4101**	0.3547**	0.1656	93
	Determination (r^2)	0.3000	0.1682	0.1258	0.0274	
Second crop, 1969	Correlation (r)	0.5870**	0.3521**	0.3335**	—	92
	Determination (r^2)	0.3446	0.1240	0.1112	—	

** Significant at the 1% level.

Influence of Seedling Length on Plant Height.

The average seedling length measured on the day of transplanting and the mean plant height recorded at different stages of growth for both parents and four groups of F_2 populations in the first and the second crops are given in Table 2 and 3, respectively. In the first crop, seedlings of tall parents were generally taller than those of short parents, and the same situation also prevailed in plant height. In the second crop, however, short parents were found to produce tall seedlings and vice versa. Nevertheless, seedlings of tall parents were capable of more rapid growth and the superiority of tall parents in plant height over short parent was apparent at the time of tillering stage (30 days after transplanting). Rice plants of both parents differed very slightly in plant height at tillering stage and substantial difference in plant height between tall and short parents was not evident until 60 days after transplanting in both crops.

Table 2. Mean seedling length before transplanting and plant height at different growth stages for both parental and F_2 populations in the first crop of 1969.

Cross combination	Population*	Seedling length (cm)		Plant height (cm)							
		At trans-planting	Rank	30** DAT	Rank	60 DAT	Rank	90 DAT	Rank	120 DAT	Rank
C 223 x Pi No. 4	P_1	35.0	1	35.3	1	73.3	1	114.3	1	144.5	1
	P_2	25.5	3	25.6	6	42.0	6	85.9	6	90.7	6
	F_2 CK	24.9	5	31.5	3	52.8	3	100.7	3	103.5	4
	F_2 T	29.9	2	32.8	2	53.9	2	102.8	2	106.6	2
	F_2 M	25.2	4	29.4	4	51.9	4	99.2	4	104.3	3
	F_2 S	19.7	6	25.9	5	49.6	5	94.3	5	102.4	5
Chianung 242 x IR 9-60	P_1	19.9	2	29.6	2	66.8	1	110.3	2	130.3	1
	P_2	15.8	5	26.0	5	55.3	6	70.9	6	86.7	6
	F_2 CK	18.6	4	27.7	3	64.2	3	102.8	4	125.3	3
	F_2 T	22.6	1	33.1	1	66.1	2	111.6	1	126.6	2
	F_2 M	18.7	3	17.0	4	63.8	4	103.2	3	123.6	4
	F_2 S	13.5	6	22.1	6	57.4	5	90.8	5	114.6	5
Tacihung native 1 x CP 231	P_1	14.2	5	27.1	5	59.8	6	82.3	6	95.7	6
	P_2	21.6	2	30.1	2	74.4	1	120.8	1	142.6	1
	F_2 CK	17.4	4	29.0	3	67.4	4	98.6	4	123.3	4
	F_2 T	22.2	1	31.2	1	70.5	2	113.4	2	137.8	2
	F_2 M	18.2	3	27.6	4	69.0	3	105.2	3	130.3	3
	F_2 S	13.6	6	24.6	6	61.7	5	88.6	5	114.9	5

* P_1, P_2=Parental Varieties. F_2 CK, T, M, S =F_2 populations of unselected, selected for tall, intermediate, and short seedlings, respectively.

** DAT=Days after transplanting.

Table 3. Mean seedling length before transplanting and plant heigh at different growth stages for both parental and F_2 populations in the second crop of 1969.

Cross combination	Population*	Seedling length (cm)		Plant height (cm)					
		At transplanting	Rank	30** DAT	Rank	60 DAT	Rank	90 DAT	Rank
Line 54233 x Nohrin 22	P_1	17.4	3	61.3	1	95.3	1	96.3	1
	P_2	16.7	5	54.3	5	87.2	4	87.2	5
	F_2 CK	18.0	2	55.9	3	84.9	5	87.6	3
	F_2 T	21.2	1	59.5	2	89.6	2	89.9	2
	F_2 M	16.7	4	55.1	4	87.3	3	87.3	4
	F_2 S	12.9	6	50.3	6	83.8	6	83.9	6
Chianung 242 x IR 9-60	P_1	17.2	5	53.6	2	106.3	1	107.0	1
	P_2	19.7	2	52.0	4	75.2	6	79.6	6
	F_2 CK	17.6	4	49.5	5	88.7	4	99.8	5
	F_2 T	24.1	1	58.3	1	96.8	2	103.7	3
	F_2 M	18.8	3	52.8	3	94.0	3	104.0	2
	F_2 S	14.7	6	46.8	6	85.6	5	100.4	4
Taichung native 1 x CP 231	P_1	20.0	4	52.4	5	74.9	5	80.8	6
	P_2	18.6	5	58.3	2	99.6	1	113.8	1
	F_2 CK	20.9	3	52.6	4	78.6	4	95.2	4
	F_2 T	26.8	1	59.7	1	91.6	2	105.3	2
	F_2 M	21.6	2	54.2	3	82.1	3	98.7	3
	F_2 S	17.6	6	49.4	6	74.8	6	92.2	5

* P_1,P_2=Parental varieties. F_2 CK, T, M, S=F_2 populations of unselected, selected for tall, intermediate, and short seedlings, respectively.

** DAT=Days after transplanting.

For F_2 seedlings, visual selection before transplanting resulted in three distinct groups with different seedling length in both crops. The difference among the mean seedling length of selected F_2 populations was highly significant for each cross in both crops (Table 4), and this difference in seedling length was maintained throughout the whole stages of growth. As a result, selected tall seedlings generally produced tall plants whereas rice plants from seedlings selected for shortness were found to be usually associated with short plant height at different growing stages. The difference in mean plant height at maturing stage was significant at 1% level in four populations of F_2 and among three selected F_2 populations except the cross of Chianung 242 x IR 9-60 in the second crop.

Average plant height of intermediate seedlings generally ranked between that of tall and short seedlings. The influence of seedling length on plant height differed slightly among crosses of rice.

Table 4. Mean squares of seedling length before transplanting and plant height at maturing stage in F_2 populations of rice crosses.

Crop season	Cross combination	Source of variation	Degree of freedom	Mean squares	
				seedling length	Plant height
First crop, 1969	C 223 x Pi No.4	F_2 populations	3	1,759.15**	219.47**
		Selected vs. unselected	1	0.02	50.96
		Among selected	2	2,638.71**	303.72**
	Chianung 242 x IR 9-60	F_2 populations	3	1,393.46**	1,526.47**
		Selected vs. unselected	1	10.32	504.95
		Among selected	2	2,085.03**	2,037.23**
	Taichung native 1 x CP 231	F_2 populations	3	1,264.18**	5,745.53**
		Selected vs. unselected	1	23.35*	861.11
		Among selected	2	1,884.59**	8,187.75**
Second crop, 1969	Line 54233 x Nohrin 22	F_2 populations	3	1,191.83**	323.52**
		Selected vs. unselected	1	81.18**	5.52
		Among selected	2	1,747.16**	482.52**
	Chianung 242 x IR 9-60	F_2 populations	3	1,558.36**	263.41**
		Selected vs. unselected	1	211.68**	309.97
		Among selected	2	2,231.70**	240.22
	Taichung native 1 x Cp 231	F_2 populations	3	1,429.89**	1,814.27**
		Selected vs. unselected	1	91.63**	602.27
		Among selected	2	2,099.02**	2,420.28**

* Significant at 5% level.

** Significant at 1% leval.

Genetic Variance of Plant Height.

Genetic variances of plant height measured at maturing stage in four F_2 populations are shown in Table 5. It was observed that genetic variances of F_2 populations from visually selected seedlings were generally smaller than those of the F_2 populations from unselected seedlings in the first crop, except the plant height from short seedlings in the cross of Chianung 242 x IR 9-30. The results obtained in the second crop were just the opposite to those of the first crop, except that from intermediate seedlings in the cross of Line 54233 x Nohrin 22. Among selected F_2 populations, genetic variances from tall seedlings were the smallest, followed by intermediate seedlings whereas those from short seedlings, the largest in the first crop, except in the cross of intra-japonica cross, C 223 x Pi No. 4 where genetic variance from intermediate seedlings was the smallest. In the second crop however, populations from intermediate seedlings showed the smallest genetic variance, followed by tall seedlings and, as in the first crop, those from short seedlings gave the largest genetic variances in 3 crosses of rice. Genetic variances for plant height were considerably lower in intra-japonica crosses in comparison with those of indica-japonica and intra-indica crosses. Differences in genetic variances of plant heignt between crop seasons was not evident

Table 5. Genetic variances of plant height at maturing stage in F_2 populations of 3 rice crosses.

First crop, 1969			Second crop, 1969		
Cross combination	F_2 populations*	Genetic variance	Cross combination	F_2 population*	Genetic variance
C 223 x Ni No. 4	F_2 CK	27.31	Line 54233 x Nohrin 22	F_2 CK	28.90
	F_2 T	16.49		F_2 T	40.82
	F_2 M	0		F_2 M	9.05
	F_2 S	23.33		F_2 S	42.81
Chianung 242 x 9-60	F_2C K	160.91	Chianung 242 x IR 9-60	F_2 CK	121.67
	F_2 T	78.11		F_2 T	149.23
	F_2 M	113.79		F_2 M	126.11
	F_2 S	251.72		F_2 S	151.10
Taichung native 1 x CP 231	F_2 CK	240.42	Taichung native 1x CP 231	F_2 CK	133.58
	F_2 T	156.73		F_2 T	193.30
	F_2 M	179.40		F_2 M	176.94
	F_2 S	194.94		F_2 S	241.12

* F_2 CK, T, M, S=F_2 populations from unselected, selected for tall, intermediate, and short seedlings, respectivly.

Estimates of Heritability.

Heritability estimates for seedling length and plant height at different stages of growth are given in Table 6. Heritability values of seedlirg length at the time of transplanting were generally low in all crosses. However, the inter-type cross, Chianung 242 x IR 9-60 gave relatively large values of heritability in both crops when compared with those of intra-type crosses of india or japonica rice varieties. The intra-japonica cross, C 223 x Pi No. 4 and the intra-indica, cross Taichung native 1 x CP 231 gave negative values of heritability for seedling length in the first and the second crops respectively, and they were replaced with zeroes.

After the transplanting of rice seedlings, heritability estimates gradually increased and when rice plants were fully matured, heritability values of plant height were considerably greater than those of seedling length in all crosses. As in the case of seedling length, heritability estimates for plant height were larger in the indica-japonica cross, Chianung 242 x IR 9-60 in both crops than either intra-japonica or intra-indica crosses. Intra-japonica cross of rice gave the lowest values of heritability for plant height at maturing stage. Heritability values differed only slightly with crop seasons for both seedling length and plant height in all crosses of rice.

Table 6. Heritability estimates for seedling length and plant height at different stages of growth in unselected F_2 populations of rice crosses.

Crop season	Cross	Heritability (%)				
		0 DAT*	30 DAT	60 DAT	90 DAT	120 DAT
First crop, 1969	C 223 x Pi No. 4	0	0	2.82	42.58	51.68
	Chianung 242 x IR 9-60	40.41	43.60	65.21	84.23	90.34
	Taichung native 1 x CP 231	15.69	16.10	29.30	66.67	88.93
Second crop, 1969	Line 54233 x Nohrin 22	34.74	45.54	58.50	54.44	—
	Chianung 242 x IR 9-60	30.46	31.71	48.57	87.76	—
	Taichung native 1 x CP 231	0	42.10	70.14	84.06	—

* DAT=Days after transplanting. 0 DAT=The day of transplanting.

DISCUSSION

It was observed that correlation coefficients between seedling length and plant height decreased gradually with the progress of rice growth, showing that considerable changes in plant height had taken place after the transplanting of rice seedlings into the paddy field. Since the development of rice plants is a dynamic process, many changes are likely to occur from young seedlings stage to the fully matured plants. Although correlation coefficients between seedling length before transplanting and plant height at maturing stage were rather small in their magnitude, especially in the first crop, there was still evidence to indicate a possible association of plant height of fully matured rice plants in the paddy field with seedling length in the nursery bed. It seems probably that seedling length may be under the influence of the same genetic factors controlling plant height. The relatively small magnitude of correlations between these two traits in this experiment may be caused by the difference in the mode of inheritance among rice varieties, since the genetic control of plant height was reported to vary from relatively simple monogenic inheritance (Chang et al., 1965 ; Aquino and Jennings, 1966) to rather complicated polygenic one (IRRI, 1967 ; Syakudo et al., 1957) ∘ Furthermore, rice varieties sampled for the calculation of correlation coefficient in this experiment may also not be sufficient to cover necessary varietal types as well as levels of plant height for an adequate manifestation of the relationship.

The effect of selection for plant height in the nursery before transplanting instead of carrying out in the paddy field at maturing stage in F_2 populations was evaluated by the comparison of mean plant weight and genetic variance. It was observed that rice plants derived from the tall, intermediate, and short seedlings were also associated with tall, intermediate, and short stature at maturing stage, the difference in mean plant height being highly significant in most cases. The consistency in the order of seedling length at transplanting and plant height at maturity clearly demonstrated that visual classification of rice seedlings into groups of different length was effective in differentiating fully d eveloped rice plants into groups with distinct plant height. It appears feasible, therefore, that selection for plant height in F_2 populations can be made before transplanting based on the length of individual seedlings.

If visual classification of rice seedlings into groups of different length was effective in increasing the frequency of genotypes with potentially similar plant height, a reduction in genetic variance would be expected within each selected population. It was found that genetic variances of plant height at maturing stage for unselected F_2 populations were generally larger than each selected F_2 population in the first crop, indicating that selection for plant height through seedling length was effective. In the second crop, however, genetic variances associated with unselected F_2 populations were considerably smaller than those associated wih selected F_2 populations especially those of indica-japonica and intra-indica crosses, showing that visual salection of seedling length was less effective under the conditions prevailing in the second crop. Among selected F_2 populations, genetic variances of plant height were considerably larger in the populations of short seedlings when com-

pared with those of either intermediate or tall seedlings for all crosses in both crops, showing that short seedlings selected in the nursery are less likely to develop rice plants with short stature whereas rice seedlings identified as either intermediate or tall are more likely to produce rice plants with relatively tall plant height. It appears likely that the efficiency of selection for short stature rice plants can be greatly improved by simply discarding the obviously taller seedlings in the nursery instead of selecting short seedlings for the transplanting.

It was found that short parents of indica varieties, Taichung native 1 and IR 9-60 produced taller seedlings than their respective tall parents in the second crop, indicating that the growth of rice seedlings produced by the short indica varieties can be greatly stimulated by the high temperature prevailing during the nursry stage. Aquino and Jennings (1966) also suggested that the dwarf gene for plant height seems to have the pleiotropic effect of strong seedling vigor. Thus, F_2 rice seedlings with dwarf gene may have better growth and phenotypically similar to seedlings with tall gene, resulting in the misclassification of the rice seedlings. This may partly explain why the selected F_2 populations were always associatd with larger genetic variances of plant height at maturing stage in the second crop.

The growth of rice seedlings may also be affected by other factors. For example, the large seeds with large endosperm usually give better growth of seedlings (Matsubayashi, 1963). Therefore, seedling length of large-sized seeds may grow considerably taller than those of small-sized seeds, even though they may have the same genetic constitution for plant height. In this experiment, the nursery bed was established in the field and sowing was made by the ordinary method. Therefore. seeds in the sparsely spaced area may germinate earlier and grow better when compared with those in the more densely spaced area. It appears likely that part of rice seedlings classified as short may not be really with dwarf gene but are short because of poor growth under the nursery conditions. When transplanted into paddy field, these poor growing short seedlings will quickly recover to the normal growth. These factors, together with others mentioned earlier, may have contributed to the large genetic variance of plant height for F_2 populations derived from short seedlings.

For visual selection to be effective, the heritability percentage of the attribute being selected must be substantially high. The heritability estimates obtained for plant height at maturing stage were generally high especially in the crosses between indica-japonica and intra-indica varieties. The high estimates of heritability obtained in this experiment were not surprising as quite high heritability values have previously been reported by other workers (Oung and Chang, 1958 ; Toriyama and Futsuhara, 1958 ; Nei, 1960). Although heritability percentages for seedling length in the nursery were rather erratic, the values of 30% or larger obtained for certain crosses in this experiment may be considered high enough for visual selection to be successful. The estimated heritability value of 30.46% for seedling length in the indica-japonica cross, Chianung 242 x IR 9-60 was actually comparable to the value of 31.7% reported for plant height in an indica x japonica cross (Oka, 1956). However, the practical value of heritability for seedling length may subject to the influence

of both internal and external factors under the growing conditions during the nursery stage.

SUMMARY

A total of 95 and 94 varieties of rice were randomly selected in the first and the second crops of 1969 respectively for the calculation of correlation coefficients between seedling length and plant height. Most correlations reached the significant level, although the magnitude of the correlations decreased with the development of rice plants.

Rice seedlings of three F_2 populations were visually classified into tall, intermediate, and short groups before transplanting to find out whether rice seedlings of different seedling length would result in matured plant with different plant height. It was found that tall seedlings generally produced tall plants whereas short plants developed from short seedlings. The differences in mean seedling length as well as mean plant height were highly significant among selected populations. Genetic variances of plant height at maturing stage for selected F_2 populations were considerably smaller than those of unselected F_2 populations for all crosses in the first crop, whereas in the second crop, the reverse was generally true. Heritability percentages estimated for seedling length ranged from nil to 40.4%, varying with crosses and crops.

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水稻苗高與株高之相關及其對選拔短稈植株之影響

張　萬　來

民國58年第1期作與第2期作分別選出95及94個水稻品種計算苗高與株高間之相關係數。就所得結果可知插秧前苗高與種植後各生育時期之株高成極顯著之正相關，惟其相關係數隨水稻之生長而逐漸遞減。

插秧前將水稻F_2集團秧苗以目測方法依其長度區分爲高、中、短三羣另以不加選拔者爲對照觀察其移植後之稻株高度及其變異。初步結果顯示高苗常導致高株而短苗則多矮株。不同苗高羣間之苗高與株高差異多達極顯著水準。經過選拔之各羣，其第1期作成熟期株高遺傳變方較對照者爲小，惟在第2期作則較對照者爲大，F_2 集團苗高之遺傳力分佈在0與40.4%之間，其大小因組合及期作而異。